E-34 | Keywords | Y3 | equipment or facility | Z4 | electricity | E29 | electrical machinery

Toshiba Energy Systems & Solutions Corporation

Adjustable Speed Pumped Storage Systems

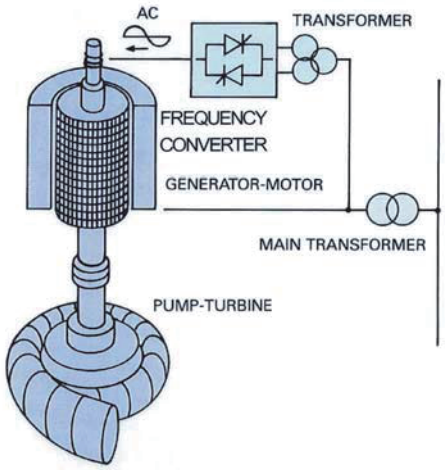
Features

◆ A pumped storage power plant can store a large amount of electric power for a long time, which contributes to leveling of demand of the power system, and is instrumental in making efficient operation of the overall power system possible.
However, conventional pumps only operate at a fixed revolution speed, so input (power) adjustment during pumping is not possible.

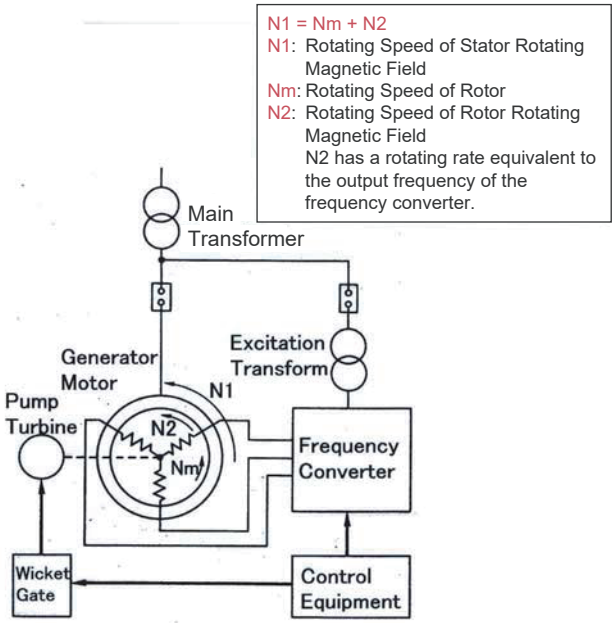
◆ By using an adjustable speed pumped storage system in which it is possible to change the revolution speed of pump, the following advantages for operation can be expected.

1) It is possible to adjust the power during pumping at night or when there is a light load, so conventional thermal power plants that are operated for frequency adjustment can be stopped, which contributes to economical operation of the power system and CO_2 reduction.
2) It is possible to absorb fluctuation in output power from renewable energy sources such as wind power or solar power generation, and thus it is possible to improve the stability of the power system.
   ⇒ This makes it easier to promote the adoption of renewable energy sources.
3) By operating the turbines at an optimum revolution speed when generating during peak load times, it is particularly possible to improve the efficiency of partial loads.
4) Instantaneously adjusting power and voltage contributes to stabilizing fluctuation in the power system.

Basic Concept or Summary



Configuration of an adjustable Speed Pumped Storage System



Explanation of the Fundamentals of Adjustable Speed Operation

1) The rotor of the generator is cylindrical and has three-phase winding.
2) Three-phase AC current flows to the rotor from a frequency converter, generating a rotating magnetic field, where the revolution speed thereof (N2) is proportional to the converter output frequency.
3) The revolution speed N2 of the rotating magnetic field is added to the revolution speed Nm at which the rotor rotates, which maintains synchronization with the rotating magnetic field N1 of the stator on the stationary side, having a relationship N1 = Nm + N2. In other words, even though the unit speed is changed the difference between the synchronous revolution speed and the rotor revolution speed is compensated by the rotating magnetic field, so the power output of the generator stator can be maintained at a fixed frequency.
4) When the change of the revolution speed is about ±5 to 8%, the input during pumping can be adjusted by approx. 60% to 100%.

Effects or Remarks

- It becomes possible to stop the thermal power plants that were additionally operated in order to adjust the frequency of the system during light loads such as at night, so it is possible to reduce the consumption of fossil fuels such as petroleum and coal.
  Explanation: In order to adjust the system frequency, the generated power output or the consumed power must be adjusted so that the generated power = consumed power. During hours when the demand for power is low such at night, many thermal power plants and hydropower plants are stopped so that the adjustment fee for the generated power is reduced. Therefore, there used to be no option but to adopt an energy inefficient way of operation of maintaining the capacity to cope with the fluctuation of the demand by operating multiple thermal power generation units with adjustable output at low output. However, since it is now possible to maintain the capacity to cope with the fluctuation of the demand after the application of the adjustable speed pumped storage system, it is possible to reduce the number of power generation units in thermal power stations operated during the night and, consequently, reduce consumption of fossil fuels.
- When generating operation, the unit can be operated at lower output power by changing the rotating speed and the adjustment range of output power can be widened.
  Explanation: The pumped storage systems are often considered to be a power adjuster, and they can serve as system stabilizers to ensure the necessary amount of power by increasing output in cases where other power sources unintentionally drop from the system during minimum output operation. Since the adjustable-speed pumped storage systems can be operated at lower output than the conventional pumped storage systems and have wider output power adjustment range between its minimum to maximum (rated) outputs, the number of the operating units in pumped storage systems and power required for next pumping operation can be reduced, and it is expected to lower fossil fuel costs and CO_2 emissions.
- By reducing the fossil fuel consumption, as described above, it is possible to reduce the amount of carbon dioxide, while benefitting economically.
- The adoption of using renewable energy sources such as wind power and solar power is advancing with the goal of reducing CO_2, however, since natural energy is used, output can be caused to fluctuate and become unstable due to weather or the like, and as the percentage of renewable energy sources used increases, it becomes difficult to adjust the frequency of the system. Particularly in regions where a lot of wind power is generated at night, it is anticipated that this fluctuation could be absorbed by an adjustable speed pumped storage system, which would assist in stabilizing the system.
- By operating the turbine at an optimal revolution speed during generating, it is possible to improve the efficiency during partial load operation by about 3%.
- It is possible to instantaneously change the output current phase angle of the converter by vector control, and thus it is possible to instantaneously change the active power and reactive power of the generator motors (during both generating and pumping). As a result, it is possible to suppress power fluctuation in the power grid and, when there is voltage fluctuation, it is possible to suppress the voltage fluctuation by adjusting the reactive power at speed comparable to the processing speed of the static VAR compensator (SVC).
- As application of adjustable speed pumped storage system, a flywheel generation system for stabilizing the system frequency has been put to practical use. In Okinawa island, (Japan), where the power system is independent, the frequency changed due to power fluctuation that occurred by start and stop of arc furnaces at a steel plant, so by installing a flywheel generator, the power fluctuation is stored as rotation energy of the rotor and flywheel, and by discharging that energy, the system frequency could be stabilized.

Installation in Practice or Schedule

Domestic
TEPCO Yagisawa Power Plant 85 MVA 1990 (Started world's first operation)
TEPCO Shiobara Power Plant 360 MVA 1995
J-Power Okukiyotsu Power Plant No. 2 345 MVA 1996
J-Power Yambaru Seawater Pumped Storage Power Plant 31.5 MVA 1999
Okinawa Electric Power Company Chujyowan Sub Station 26.5 MVA flywheel generator 1996 (Application)
TEPCO Kazunogawa Power Plant Unit 4 475 MVA 2014
Hokkaido Electric Power Company Kyogoku Power Plant Unit 1 230 MVA 2014
Hokkaido Electric Power Company Kyogoku Power Plant Unit 2 230 MVA 2015

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